Lightweight
Composite Mirrors for Space

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Statement of the problem:

- Monolithic SiC mirror technology (α-SiC, β-SiC, siliconized SiC) suffer from poor fracture toughness. They exhibit intrinsic size limitation.
- Glass technology – highly brittle, lengthy manufacturing time.

Objective:

- Demonstrate the use of light weight SiC-based composite technology for large space optics applications

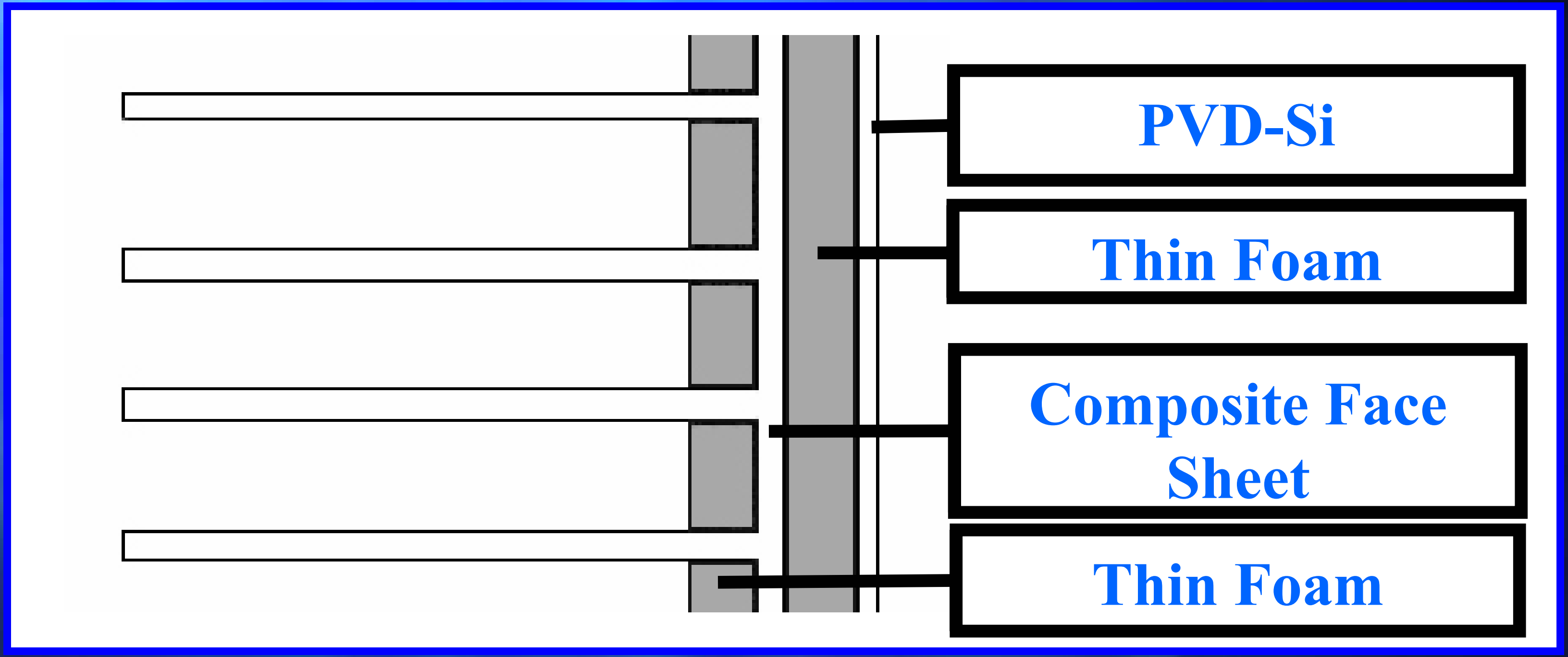
Two Applications

- UV and EUV optics (GSFC)
- Lidar and instrument applications (LaRC)

Uniqueness of the Approach

- Use of functional composites C-C, or SiC-C to render lightweight structures (tailored for an application)
- Use of foam and/or cladding to solve the print-through CTE microcracking problem (tailored for an application).
- Use of PVD-Si to enable robust optical manufacturing (diamond turning)
- Use of post polishing to attain desired microroughness

Schematic of Hybrid Composite/Foam Mirror (UV)



Functionality of Different Mirror Constituents:

Composite honeycomb – very high stiffness, designed for the first eigen frequency, highly non-brittle, low density, CTE matched to Si.

- Foam – tailored modulus eliminates the nano crazing (elastic modulus relief) and print-through.

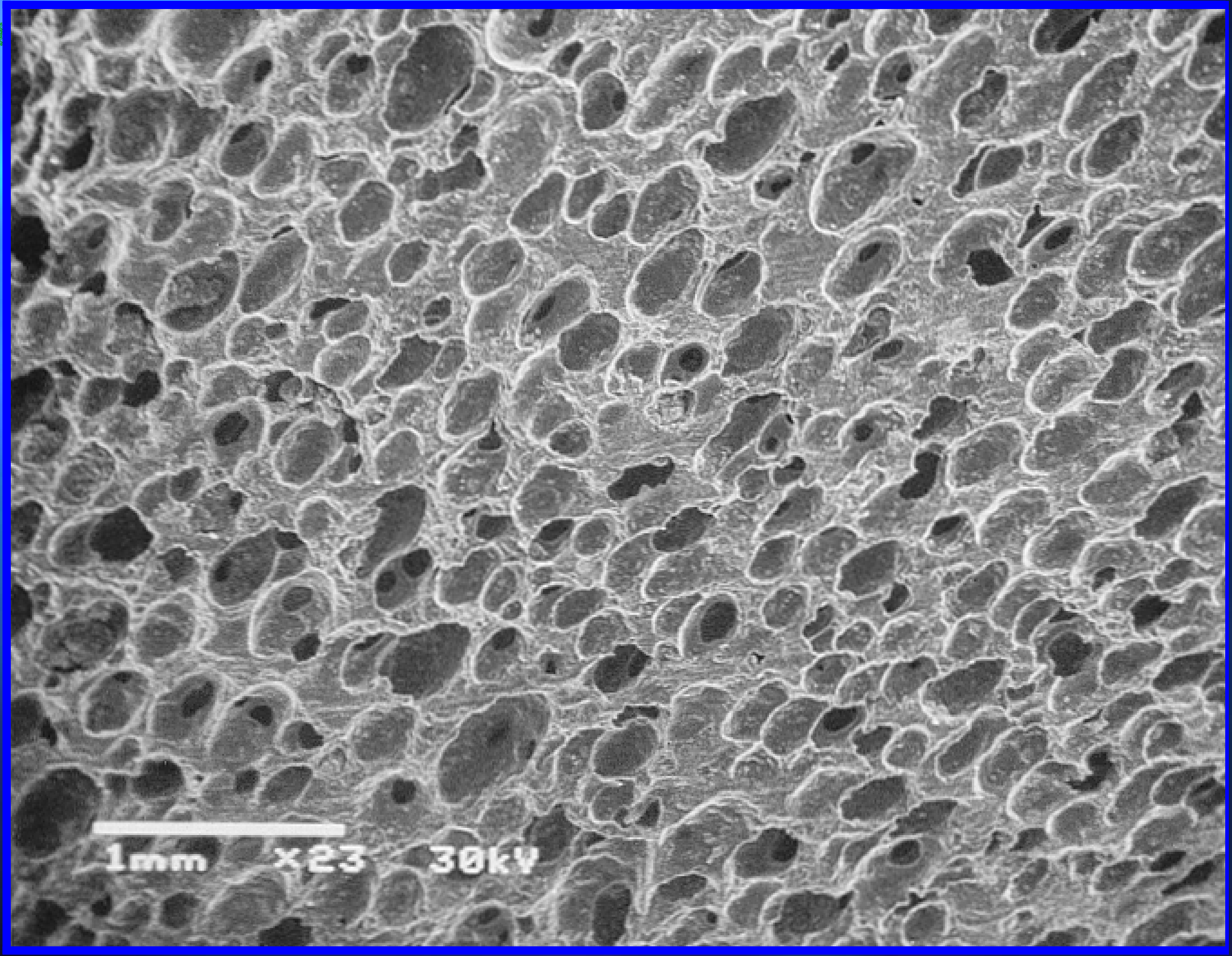
- Si coating – optical surface.

Mirror Materials

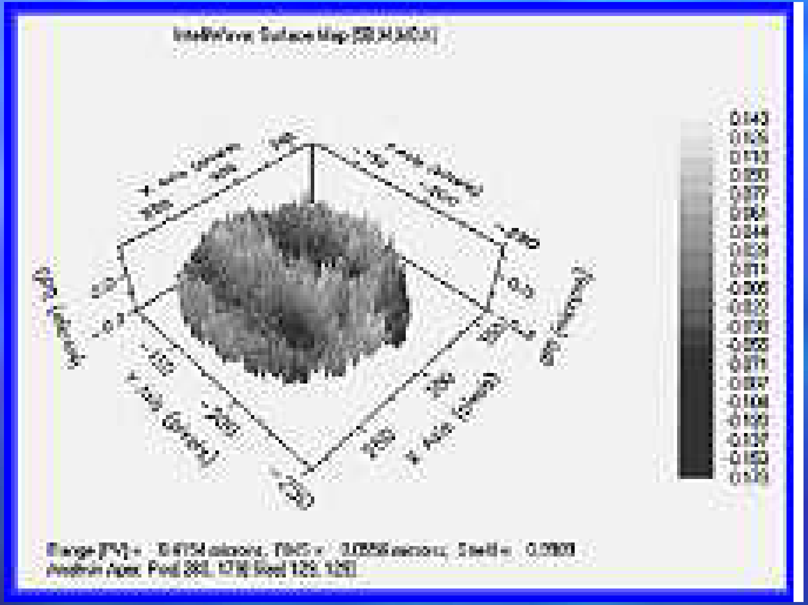
	RBSiC	CVD SiC	Si	C-C	Carbon foam
Density (g/cm^3)	2.7	3.21	2.3	1.95	1.2
CTE (ppm/K)	2.0	2.4	2.6	0.2	3.5
Thermal conductivity (W/mK)	125	325	150	350	260
Elastic Modulus (GPa)	238	466	110	385	2
Thermal Distortion Parameter ($W.m^{-1}x10^7$)	6.25	13.5	4.2	350	15
Inertial Loading Parameter ($N.m.Kg^{-1}x10^6$)	88	145	48	180	25
Thermal Stress Parameter ($W.m.N^{-1}x10^{-4}$)	2.6	2.9	3.8	50	7.5
Polishability (angstroms rms)	20	3	3	5	-

	Mo	Al	Be	ULE 7971	Zerodur
Density (g/cm^3)	10.2	2.7	1.85	2.2	2.55
CTE (ppm/K)	5.4	25	11.4	0.03	0.15
Thermal conductivity (W/mK)	134	237	216	1.3	6
Elastic Modulus (GPa)	250	76	303	67	90
Thermal Distortion Parameter ($W.m^{-1}x10^7$)	2.5	0.95	1.9	4.3	4.0
Inertial Loading Parameter ($N.m.Kg^{-1}x10^6$)	24.5	28.1	164	30.4	35.3
Thermal Stress Parameter ($W.m.N^{-1}x10^{-4}$)	1.0	1.25	0.63	6.4	4.4
Polishability (angstroms rms)	5	5	10	3	3

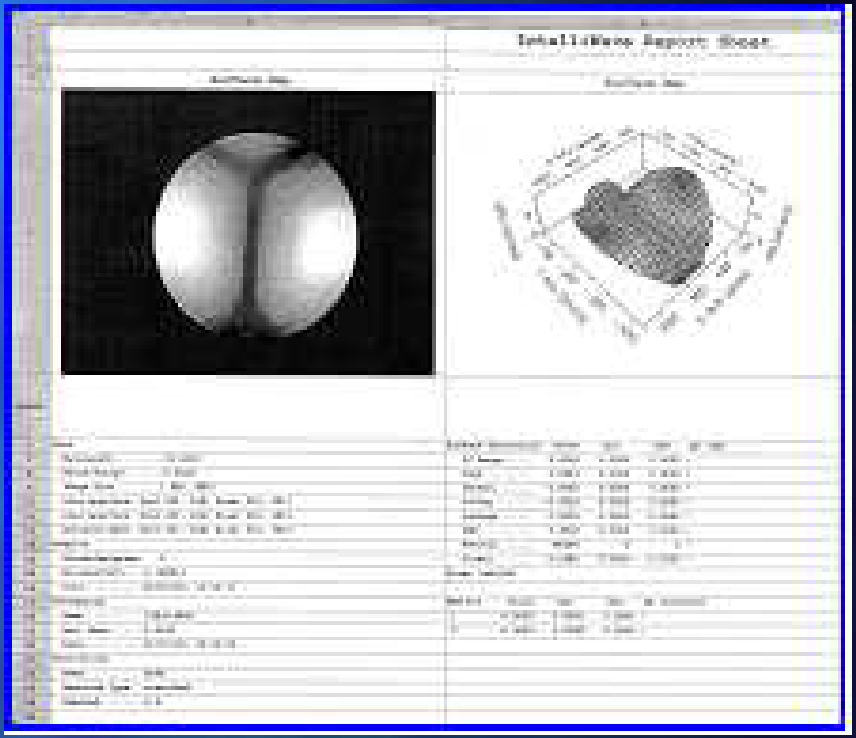
SEM Image of High Thermal Conductivity Graphite Foam



Interferogram at the Rib Section



With Foam



Without Foam

Risk Mitigation Strategy:

4” mirrors used as “pathfinders”

Established very good microroughness at high frequency (under 1 nm microroughness at six different locations).

Development of ultrafine polishing while maintaining the P/V.

Established no “print-through”.

Establish diamond turning on the Si coating, representative of an 18” mirror.

Establish the ability to figure the mirror in a cost-effective fashion.

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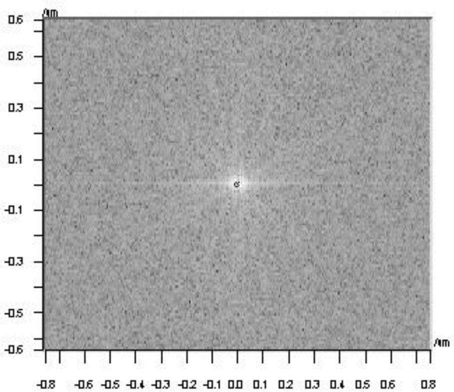
(Risk Mitigation Strategy: cont'd)

18 inch mirror pathfinders:

- Establish adherent PVD Si coating
- Establish diamond turning
- Establish post-polishing

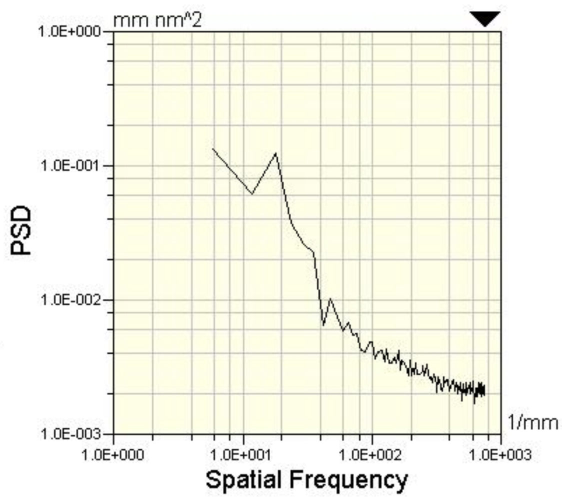
Power Spectrum Distribution of Si Coating

PSD Plot



2D RMS: 0.93 nm
2D low cut off: 0.00 /mm
2D high cut off: 10.00 /mm

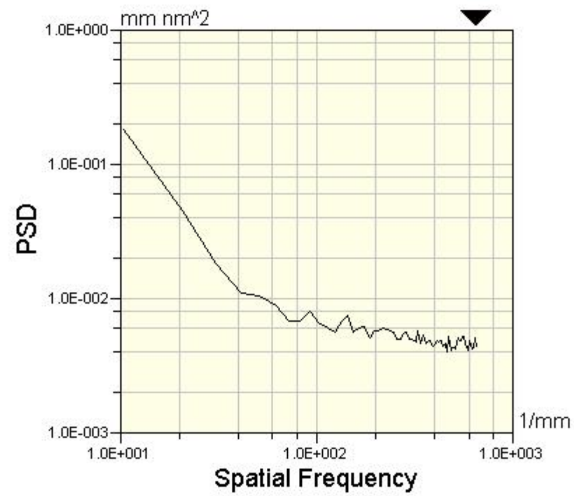
X Average PSD



X Average PSD Stats:

Low Cutoff: 0.000 /mm
High Cutoff: 0.000 /mm

Y Average PSD



Y Average PSD Stats:

Low Cutoff: 0.000 /mm
High Cutoff: 0.000 /mm

Small SiC Mirrors

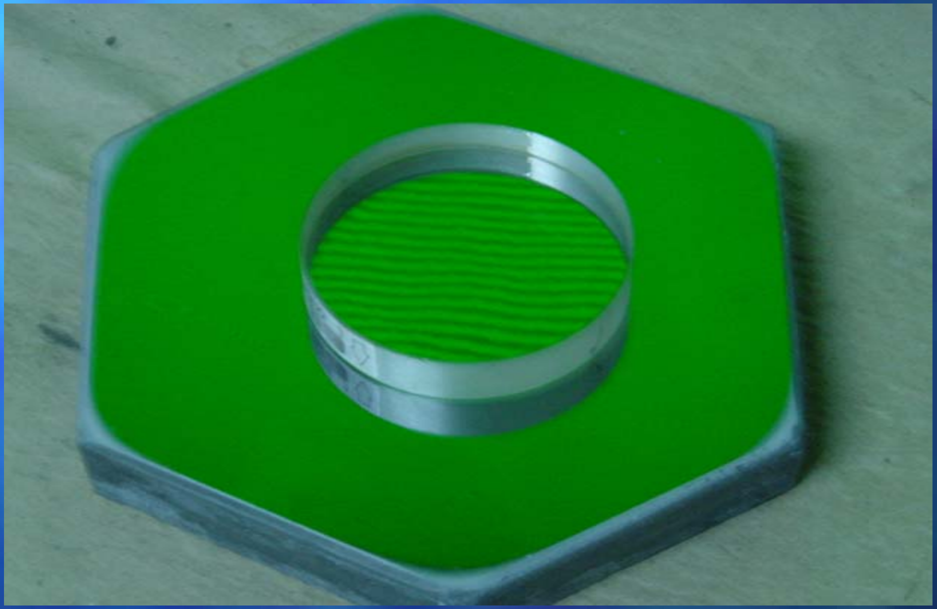
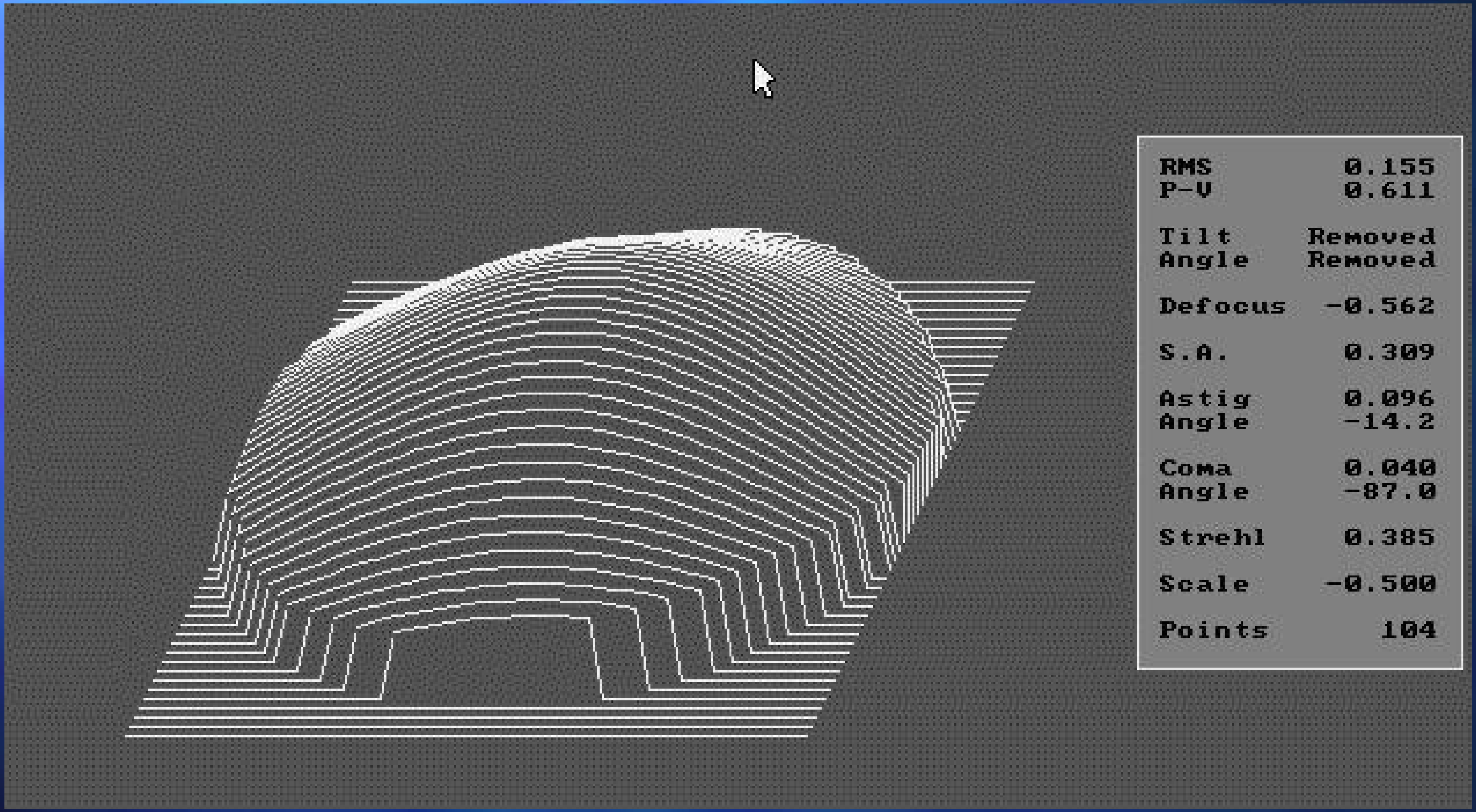
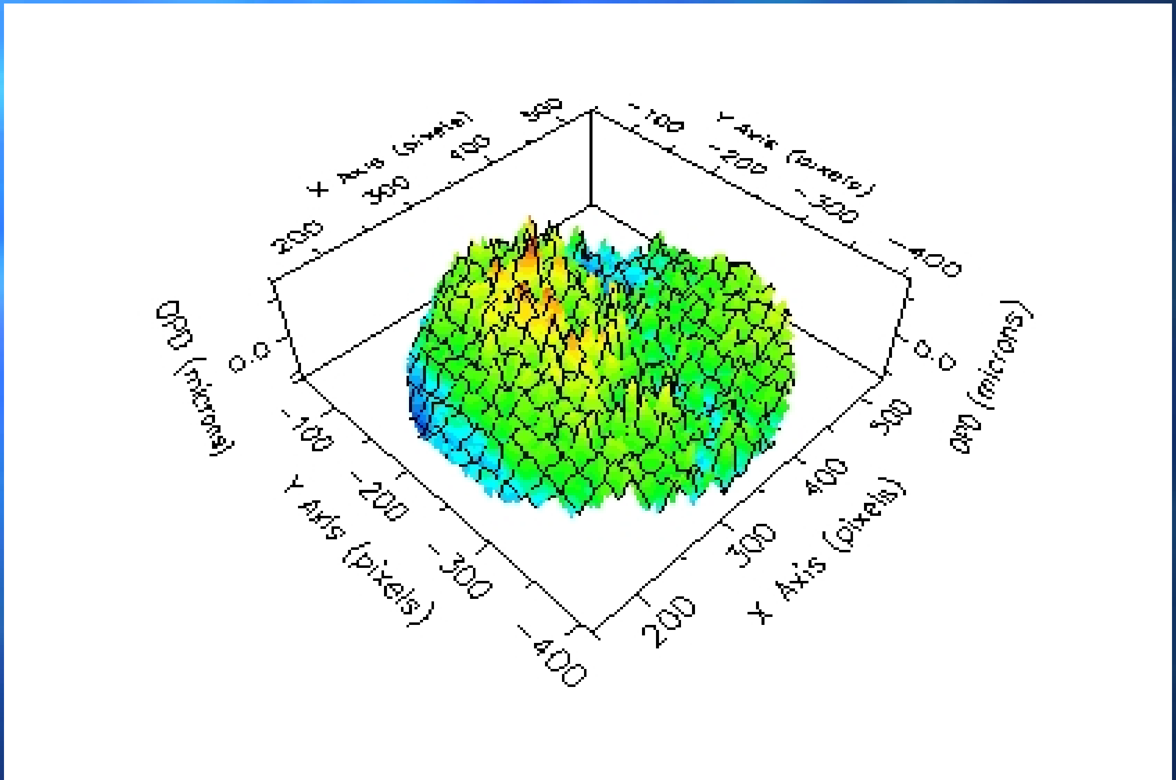


Figure of 4" Mirror



Rib Section Interferogram Showing No Print-through (100 nm P/V)



Deliverables

- GSFC
  - one 4” 1 nm microroughness
  - one 18” flat (6kg/m2)
  - one 18” concave (10 kg/m^2, 1 nm rms)
- LeR
  - one 18” (sol-gel) 4 kg/m^2
  - several composite membranes for scanning mirrors